Climate Change And Waste Management: A Deep Dive

Programming & Quality in Analytics Final Project

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Git Repo: https://github.com/vibhananda28/2022Fall_projects

Overview

- Climate change is often linked to the dooms day that bestows upon the world today. Waste generation and management is known to be a leading cause of global warming.
- Developed countries have more resources at their disposal to treat waste appropriately and are yet known to generate more waste than the developing economies. We find more guides than analysis to evaluate how the developed world is managing its waste.
- In this project, we focus on how developed countries manage and treat waste and how it is related to some economic factors like education attainment, population density and poverty. We are going to use a variety of visualizations and data analysis tools.

Data

- We have **2 datasets**: World Bank's World Development Indicators (education, population, poverty focused) and OECD waste database (waste management related variables) (data ranges from 1990-2021).
- **Variables include**: Education expenditure by government, total educational attainment (at least until bachelor's degree), educational attainment for women, poverty statistics, population growth and levels, Forest coverage, GDP per capita (real) and growth, municipal waste generation, % material recovery (recycled + composting) etc.
- **Merged dataset** is a panel/longitudinal dataset which contains 44 variables (1076 * 44) per country, for all years.
- Data types were mostly float, but a few int and string types were there too.

Year	COU	Country	Composting	Disposal%	Landfill%	Material_rec	Recovery%	Recycling%	Amt_for_rec	Composting	Electronic_w	Household_v	Landfill	Municipal_w	Municipal_w	Municipal_w	Municipal_w	Municipal_w	Recycling	Total_Incine	Waste
1990	AUT	Austria	23.171	56.277	56.277	34.529	43.723	11.358	1536	814			1977	3204	414.814	100	68.963	3513	399	312	
1990	BEL	Belgium	5.983	66.751	43.853	11.108	33.249	5.125	1317	237			1737	3436	343.375	100	71.131	3961	203	1784	
1990	CHE	Switzerland	6.341	22.68	22.68	28.547	77.32	22.207	3170.6	260			930	4100.6	616.366	100	86.675	4100.6	910.6	2000	2
1990	CHN	China (People's Republic of)												67668		100	57.254				
1990	DEU	Germany												49857	630.67	100	94.408				
1990	ESP	Spain	20.33	76.21	74.345	20.846	23.79	0.516	3000.05	2563.72		12610.78	9375.53					12610.78	65.13	606.4	
1990	GBR	United Kingdom							700					27100	474.32	100	79.814		700		2
1990	GRC	Greece		94.043	94.043	5.957	5.957	5.957	178.7				2821	3000	293.37	100	67.461	2999.7	178.7		
1990	HUN	Hungary	0	92.807	92.807	0	7.193	0	300	0			3871	5500	530.012	100	120.826	4171	0	300	
1990	ITA	Italy												20000	350.58	100	69.063				
1990	JPN	Japan			19.476	5.309		5.309					9790	50256.625	403.651	100	91.654	50267.83	2668.87	36192	
1990	KOR	Korea		93.577	93.577	4.645	4.645	4.645	1423.5			30646.13	28677.69	30646.1	714.055	100	180.804	30646.13	1423.5	544.95	
1990	LUX	Luxembourg												223.6	585.678	100	78.385				
1990	NLD	Netherlands												7430	496.477	100	77.973				
1990	NOR	Norway												2000	553.986	100	72.595		100		
1990	NZL	New Zealand											3330	3330	979.936	100					
1990	POL	Poland												11098	292.359	100	90.774				
1990	PRT	Portugal												3000	303.172	100	63.768				
1990	SWE	Sweden	3.125	43.75	43.75	15.625	56.25	12.5	1800	100			1400	3200	373.51	100	84.813	3200	400	1300	
1990	USA	United States	2.017	69.751	68.694	15.96	30.249	13.944	57153	3810	3420		129791	188939	749.4	100	85.549	188940	26345	28939	11
1991	AUT	Austria	11.119	57.617	57.617	29.567	42.383	18.448	1174	308			1596	3126	402.177	97.566	67.284	2770	511	341	
1991	BEL	Belgium	6.038	70.246	46.311	11.346	29.754	5.308	1222	248			1902					4107	218	1739	
1991	CHE	Switzerland	7.405	17.279	17.279	30.885	82.721	23.479	3351.2	300			700	4131.2	614.87	100.746	87.322	4051.2	951.2	2100	2
1991	CHN	China (People's Republic of)												76360		112.845	64.608				
1991	ESP	Spain	14.701	80.941	79.711	15.37	19.059	0.669	2460.13	1897.53		12907.91	10289.07					12907.91	86.41	634.91	
1991	ITA	Italy												23200	406.389	116	80.113				
1991	JPN	Japan			16.542	6.063		6.063					8458	51132	409.286	101.742	93.25	51128.94	3100	36169	
1991	KOR	Korea		91.02	91.02	7.356	7.356	7.356	2476.89				30646.5	33669.8	776.282	109.867	198.643	33670.01	2476.89	546.62	
1991	LUX	Luxembourg												216.8	561.135	96.959	76.001				

Approach

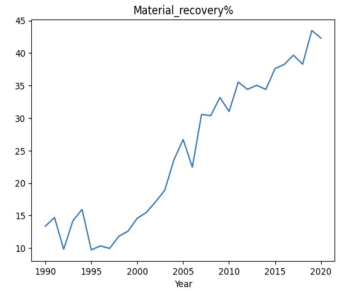
- We created a separate utils.py file to store all our functions and imported that as a module in our jupyter-notebooks (1 each for all hypothesis).
- The datasets needed cleaning, reshaping and renaming to be merged (inner join).
- All hypothesis were evaluated using a subset of the merged df, time series plots, scatter plots, and correlation tests and correlation matrix.
- Pandas was extensively used along with matplotlib and seaborn for plotting.

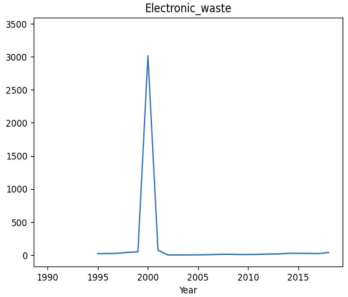
Hypothesis 1

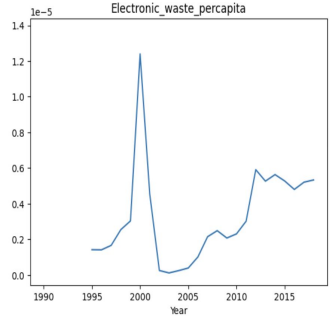
- Electronic waste generation (overall and per capita) as well as percent of material recovery (recycling + composting) have a strong relationship with education.
- We believe that developed countries should have higher material recovery rates given the resources at their disposal. Also, we believe that higher education should be correlated with higher material recovery.
- Additionally, we also believe that more educated people generate more electronic waste given the affordability and higher use of technology.
- We will use both education attainment and education expenditure statistics to evaluate the relationship.

Hypothesis 1

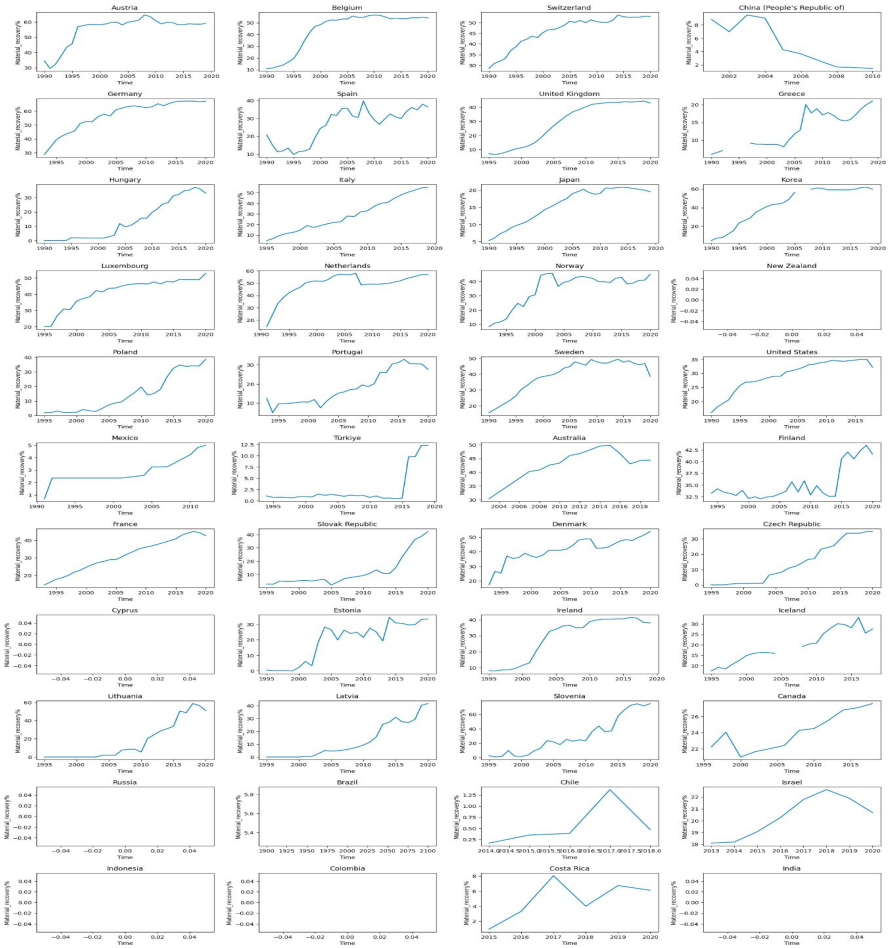
- **Distribution**: density plots showed that all dependent variables were non-normal, hence median values were evaluated for many grouped charts.
- **General observations**: United States generates the most electronic waste per capita and overall (8000 tonnes). Germany has the most amount of material recovery over time (60%).
- Material recovery peaked in 2019. Overall, it has been higher in the recent years.
- Electronic waste generation peaked in 1990 and 2000. For all other years, including recent ones, it has been negligible.
- Electronic waste generation per capita also peaked in 1990 and 2000. However, it has had considerable shares in other years as well.
- **Time trends**:
  - Material recovery has had a sharp upward trend post 1995.
  - Electronic waste generation had a peak around 2000 but flattened quickly and remained so.
  - Electronic waste per capita had a similar peak and fell down right after. However, It has had an upward trend in the recent years.







Hypothesis 1



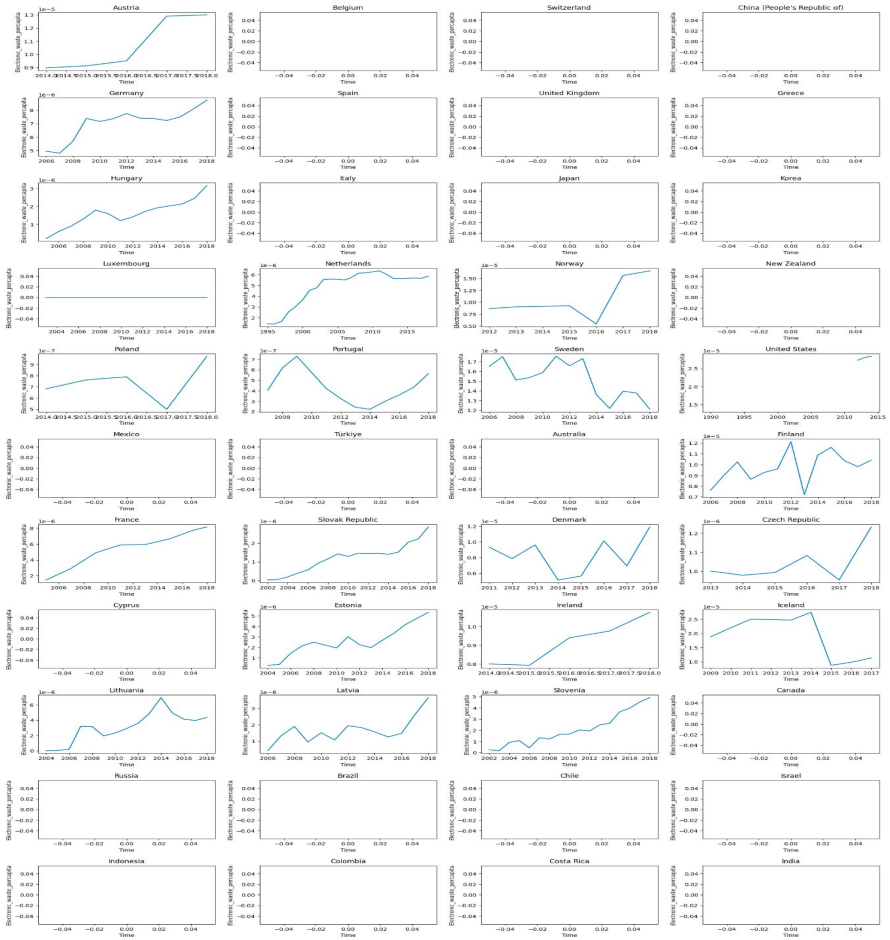
Material Recovery (%) trends for each country

1. **Overall Downward trending**: China has had a sharp downward trending curve since 2000 (no data prior to it). Chile and Israel have had a downward trending curve in the recent years, since 2018.

2. No data: New zealand, Cyprus, Russia, Brazil, Indonesia, Colombia and India have no data to plot.

3. **Upward trending**: All other countries have had an upward trending curve.

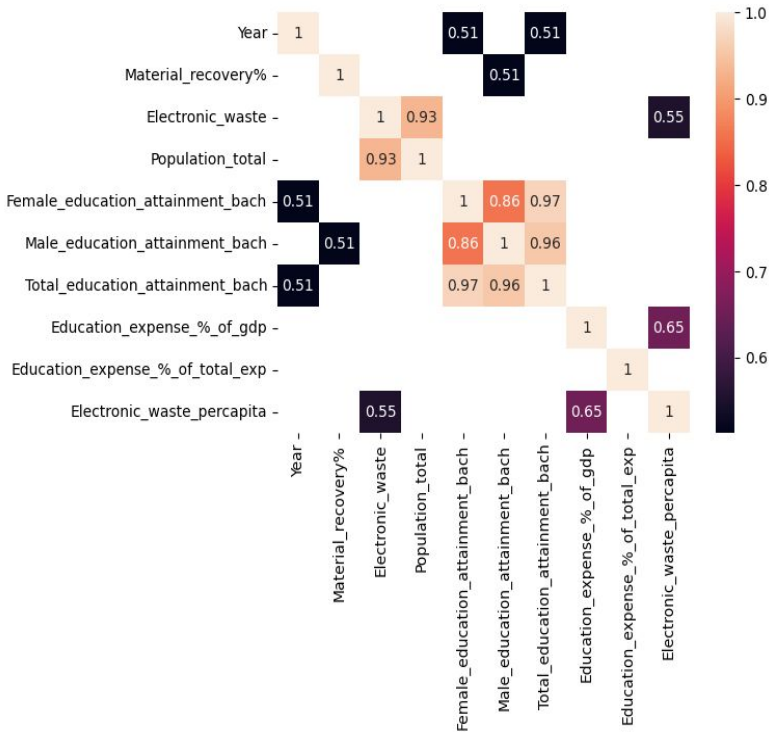
Hypothesis 1



Electronic Waste per Capita trends for each country

- **Downward trending**: Sweden has had an overall downward trending curve.
- No data: Belgium, Switzerland, China, Spain, UK, Greece, Italy, Japan, Korea, New zealand, US, Mexico, Turkey, Australia, Canada, Russia, razil, Chile, Israel, Indonesia, Colombia, Costa Rica and India have no data.
- **Upward trending**: Lithuania, Latvia, Slovenia, Ireland, Estonia, France, Slovakia, Austria, Germany, Hungary, Netherlands, Norway, Poland, Portugal, Denmark (recent years), Czech Republic; all have upward sloping curves.
- Luxembourg has had a constant path all along.

Hypothesis 1: Correlation



Scatter plots:

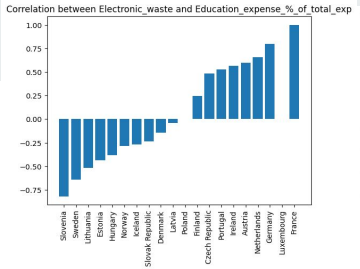
- More material recovery % seems to have a linear relationship with higher education attainment.
- There does not seem to be an obvious relationship between education attainment and electronic waste generated per capita and overall.
- At higher levels (4-7%) of education expense as % of GDP, there is a linear relationship with material recovery. For education expense as % of total government expense has a linear relationship with material recovery at its lower levels (5-15%).

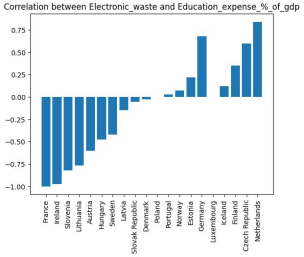
Strong Correlation matrix (absolute values):

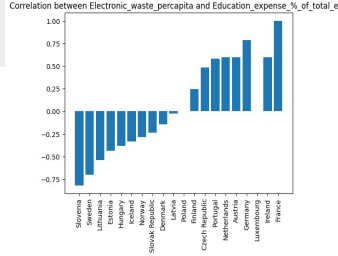
- Electronic waste generated per capita is also strongly correlated with education expense as a % of GDP (65%).

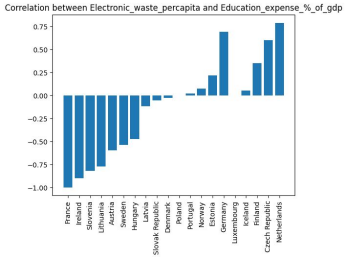
Hypothesis 1: Spearman Correlation for each country

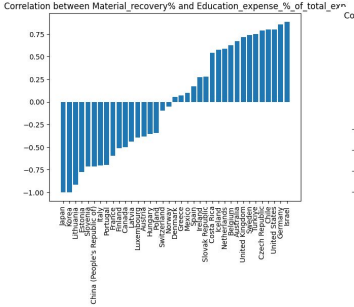
- Most countries met our hypothesis regarding material recovery for all education related variables (expenditure and attainment).
- However, for expenditure, some countries also showed a very strong negative correlation (e.g. Japan, Korea & China)
- Gender based education does not seem to play any role in material recovery or electronic waste generation.
- Approximately, equal number of countries had both a positive and negative correlation with electronic waste generation (overall and per capita). Hard to decipher an overall pattern.

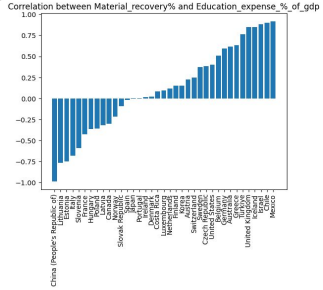


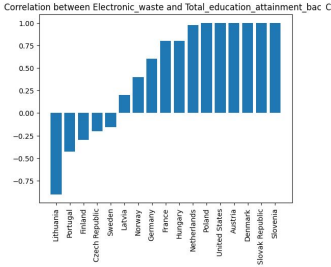


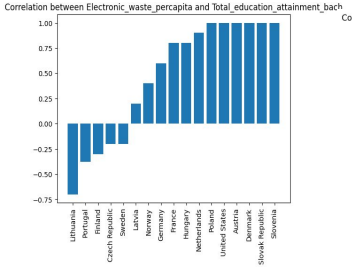


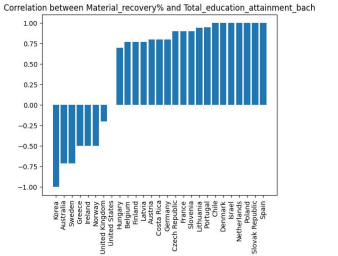








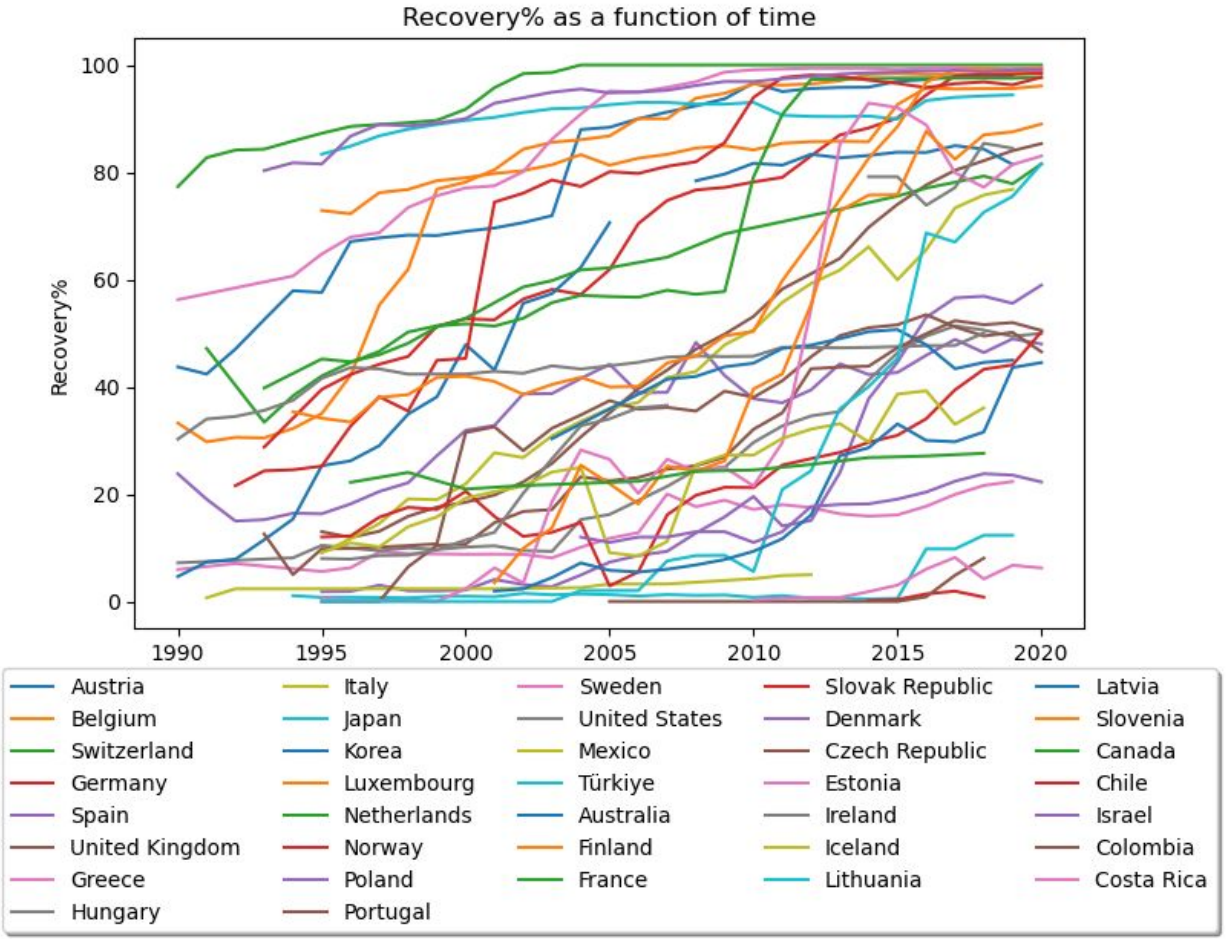




Hypothesis 2

We expect the waste production trend to be downwards and recovery % to be upwards, especially post 2015 when all UN members agreed to UN's Sustainable Development Goals (Goal 13: Climate action- Take urgent action to combat climate change and its impacts). The Paris Climate Change Agreement was also launched in 2015 making the hypothesis more sound.

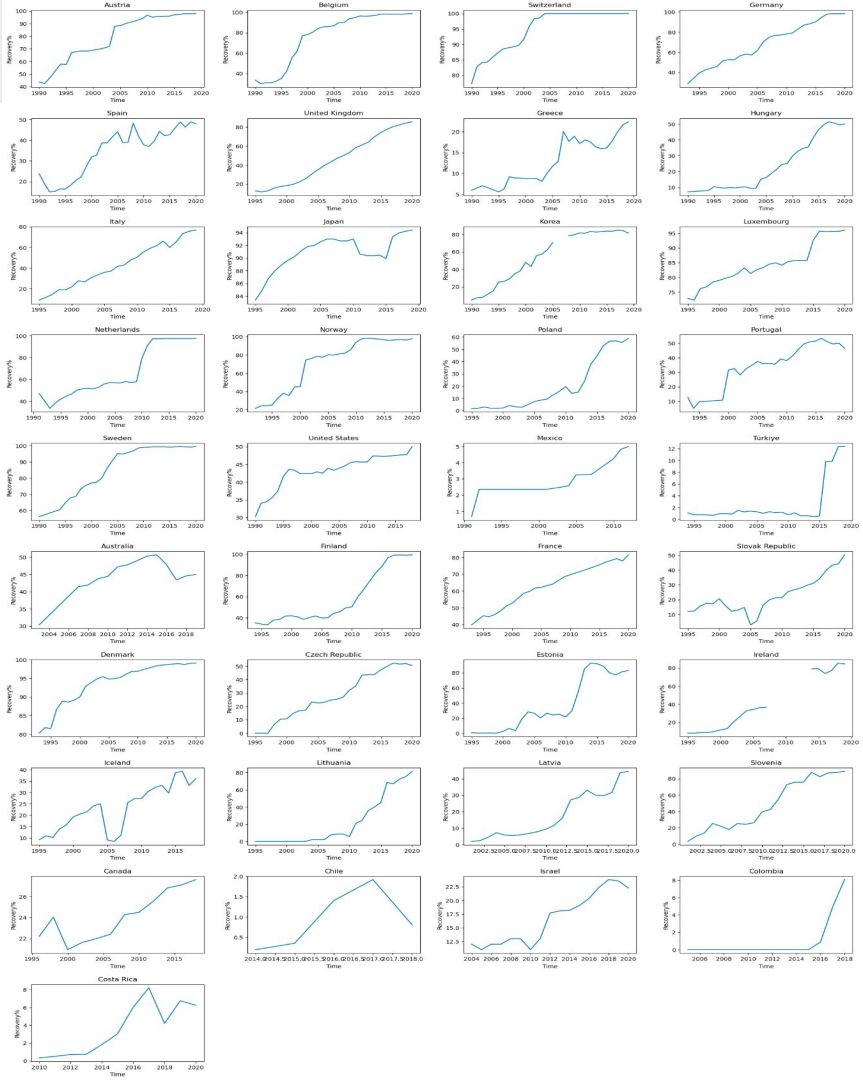
Hypothesis 2



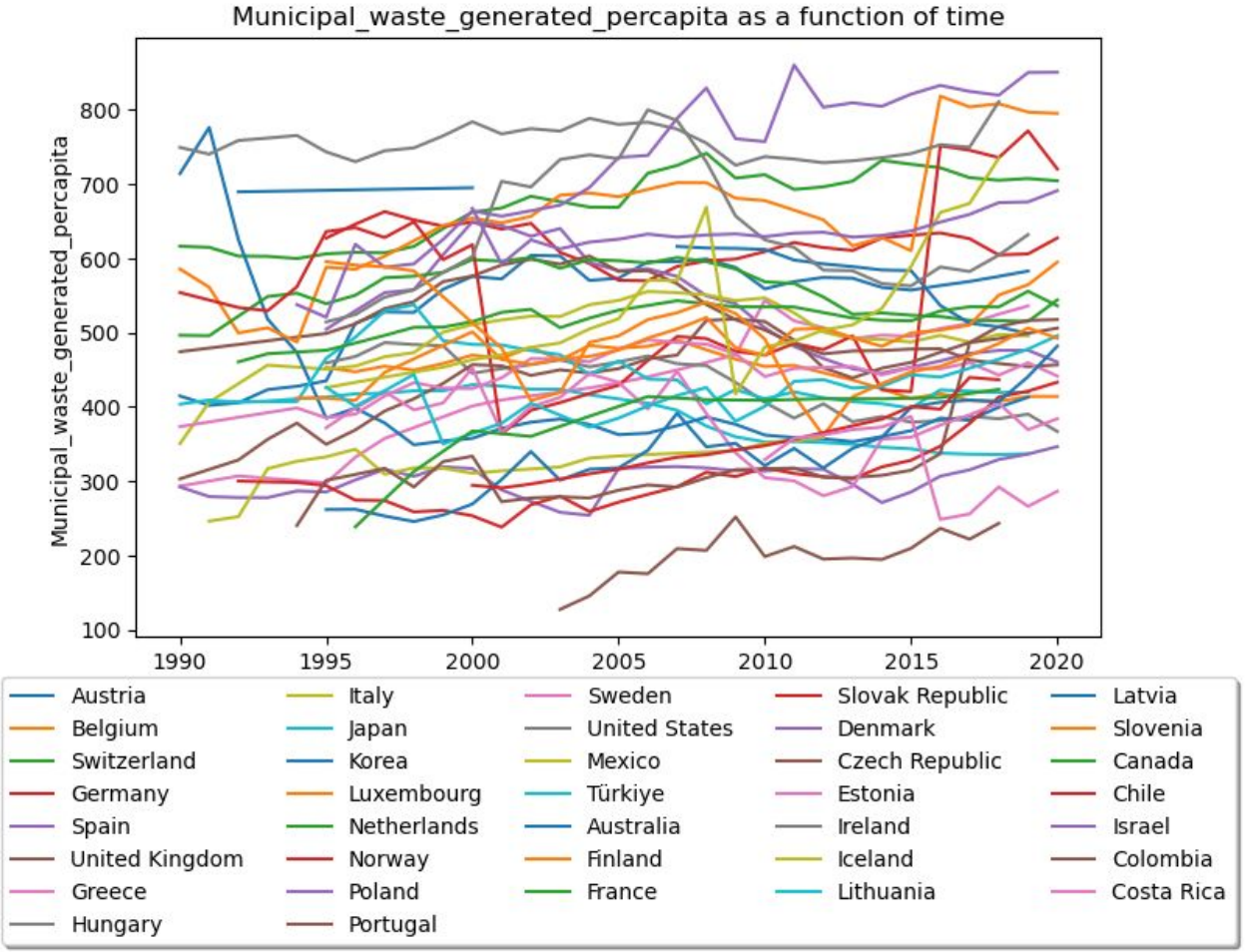
Hypothesis 2

Observations 1

1. Most of the countries show an increasing trend of "Recovery%" with time.
2. Countries like Costa Rica, Chile show an increasing trend first but decrease after a point. The "Recovery%" of Chile stays under 2% that is really less. Costa Rica's Recovery % oscillates between 4% to 6% after the year 2016.
3. The Recovery% of Mexico also reaches 5% only at the highest point in the graph.
4. Austria, Belgium, Switzerland, Germany, Denmark and other european nations show a high growth and high magnitude of Recovery%.



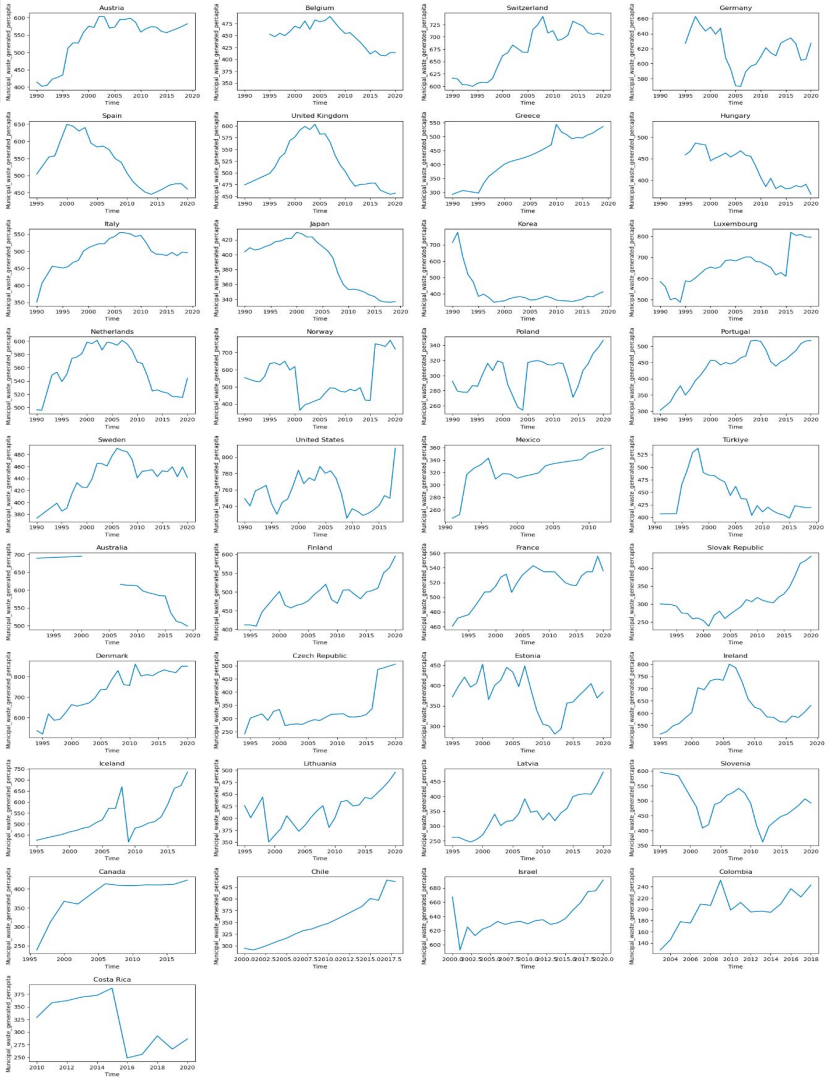
Hypothesis 2



Hypothesis 2

Observations 2

1. Countries show varied trend of Municipal waste generated. While some increase overall, the others show a decreasing trend of generation of Municipal waste.
2. Austria, Switzerland, Greece, Poland, Chile, Israel and others show an increasing overall trend for municipal waste generated per capita.
3. Spain, Hungary, Korea, Japan, Mexico and other similar countries show a decreasing overall trend.

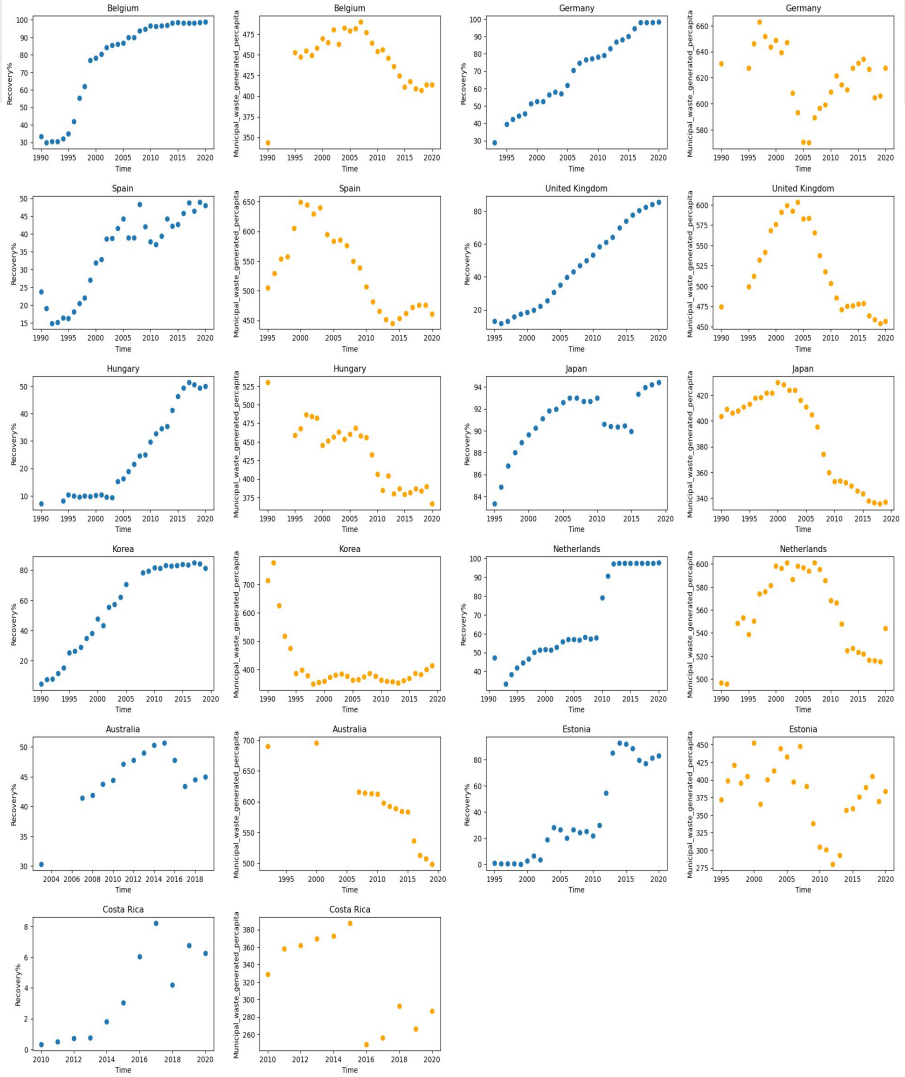


Hypothesis 2

Analysing different country groups based on spearman correlation coefficient

Group 1 corr<0.-25

1. The countries shown in the above group show a negative correlation. We expect that there will be a rising trend for Recovery % and a decreasing trend for Municipal waste generated per capita.
2. Almost all the countries show the above mentioned trend. Some countries like spain and united kingdom have an initial increase in Municipal waste generated per capita but later it decreases overall.

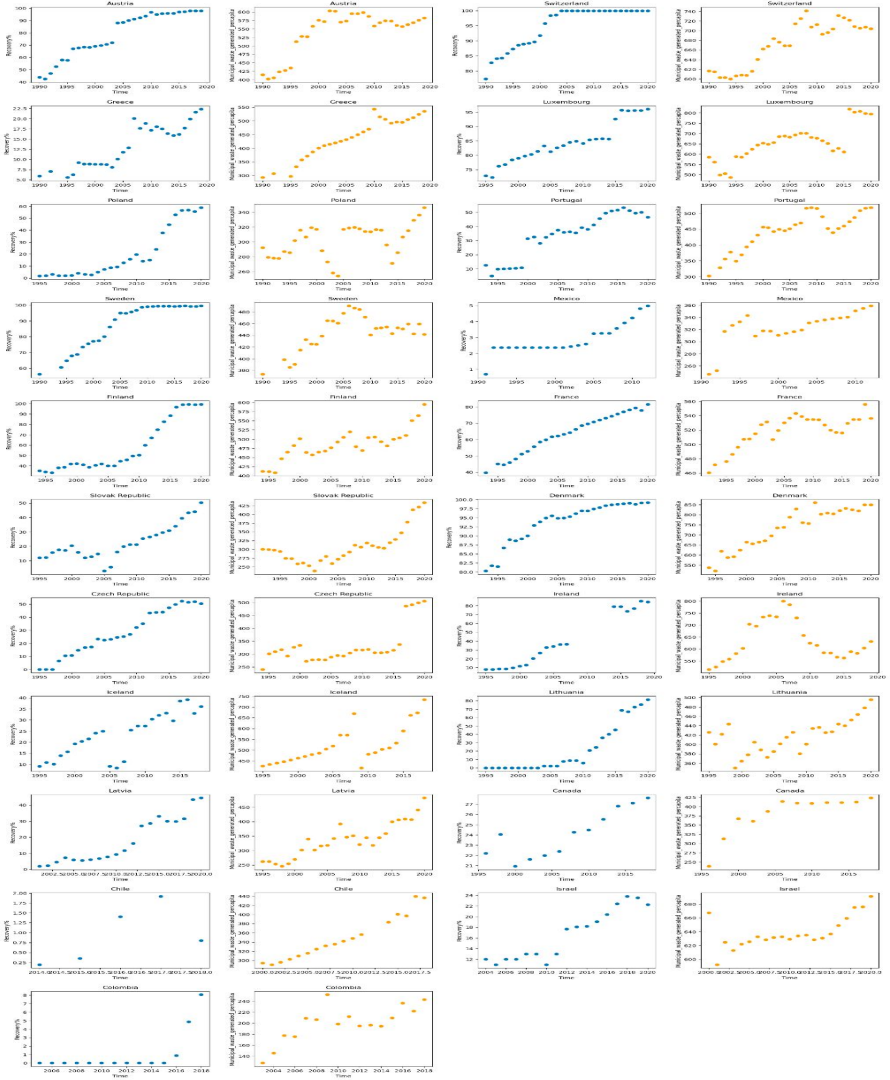


Hypothesis 2

Analysing different country groups based on spearman correlation coefficient

Group 2 corr>0.25

1. The countries shown in the above group show a positive correlation. We expect that there will be either a rising or decreasing trend for both Recovery % and Municipal waste generated per capita.
2. Almost all the countries show the an overall increase in both Recovery % and Municipal waste generated per capita.

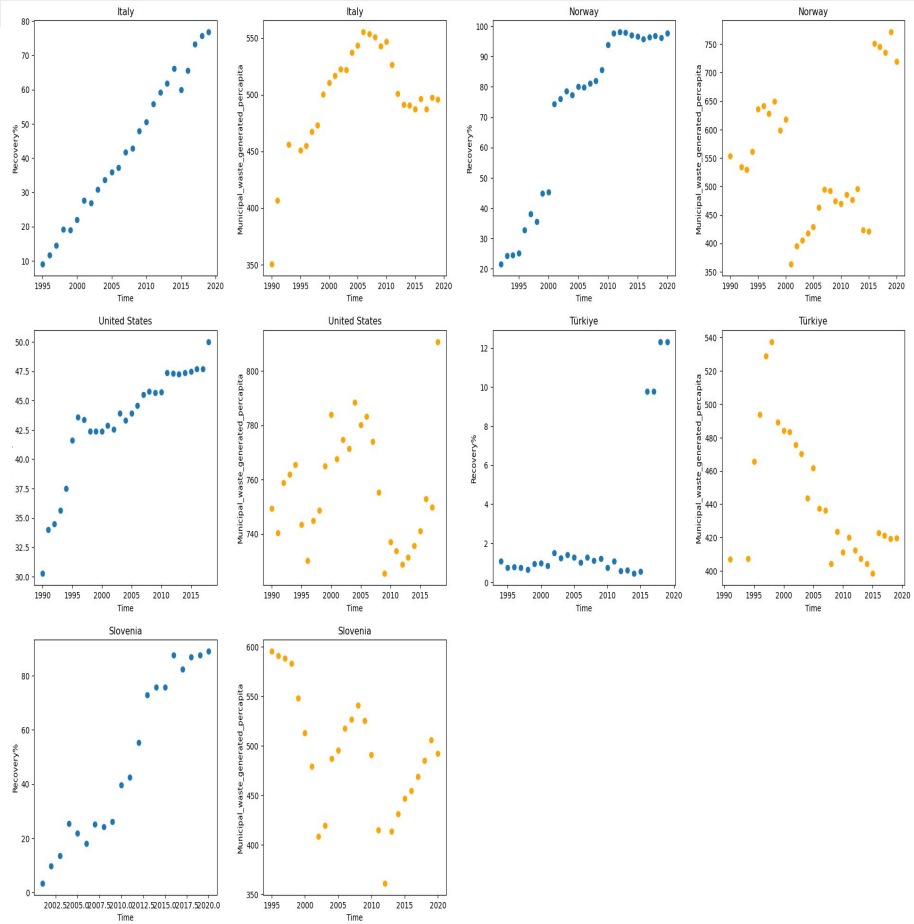


Hypothesis 2

Analysing different country groups based on spearman correlation coefficient

Group 3 -0.25<corr<0.25

1. The countries shown in the above group show least correlation between Recovery % and Municipal waste generated per capita.
2. Italy and Norway seem like they show increasing trends on both variables but on observing Municipal waste generated per capita, it can be seen that it does not change by a large magnitude.

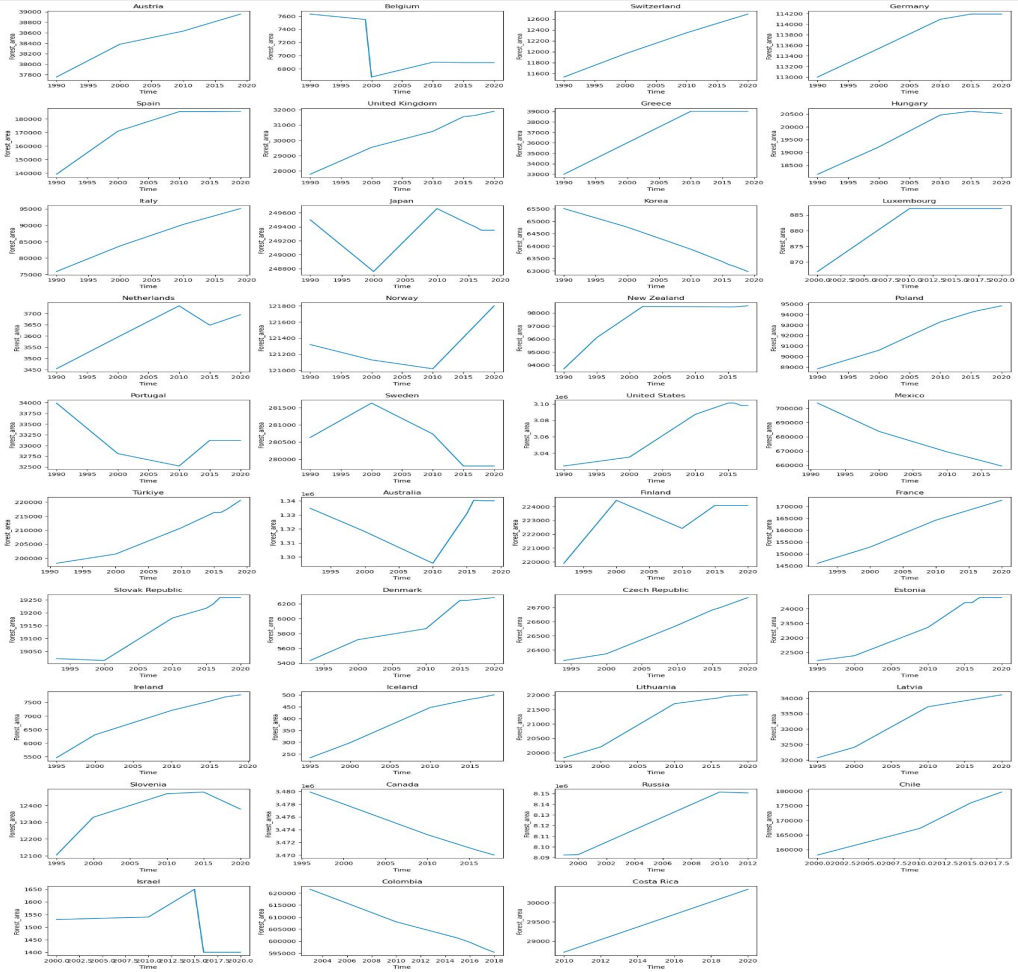


Hypothesis 3

We expect some co-integration between waste generation and forest cover depletion. We will explore the relationship between the two to draw some insights. We will strive to use both WB and OECD data for this.

Hypothesis 3

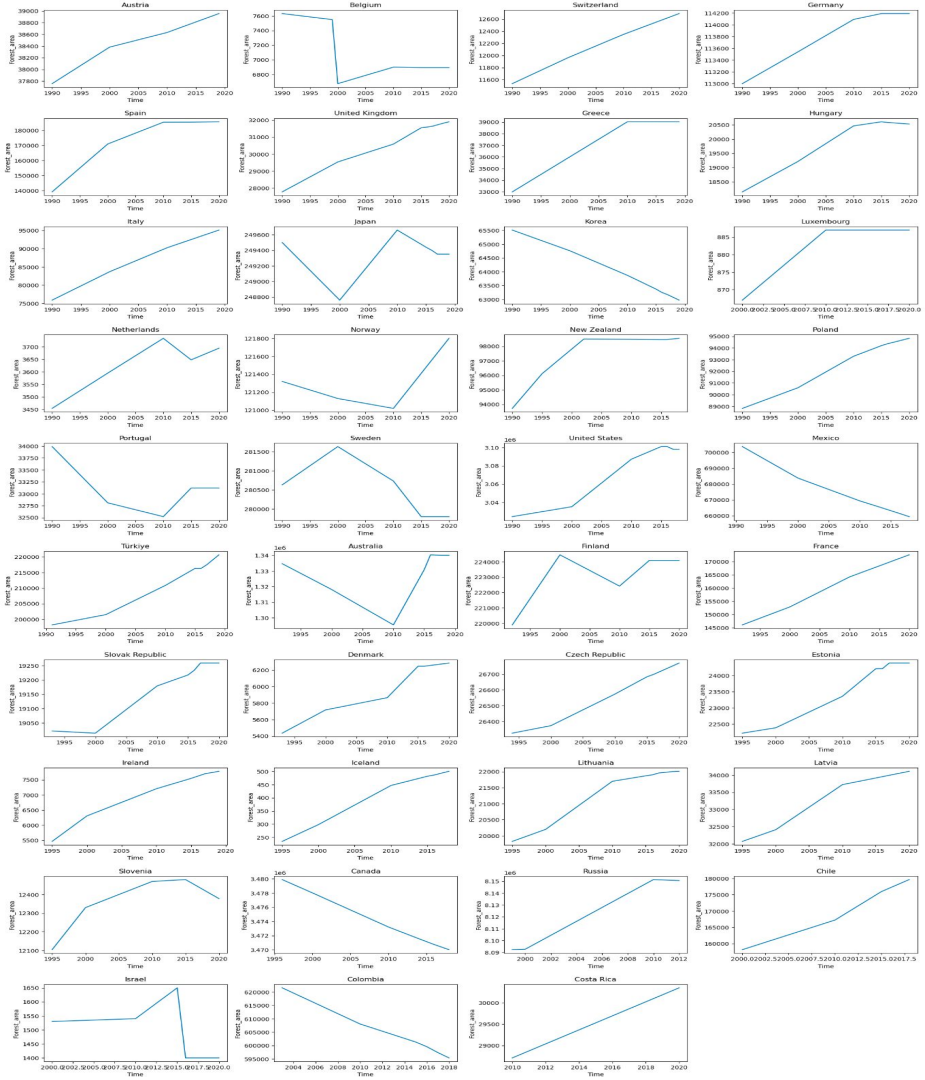
Forest Area as a function of time for different countries



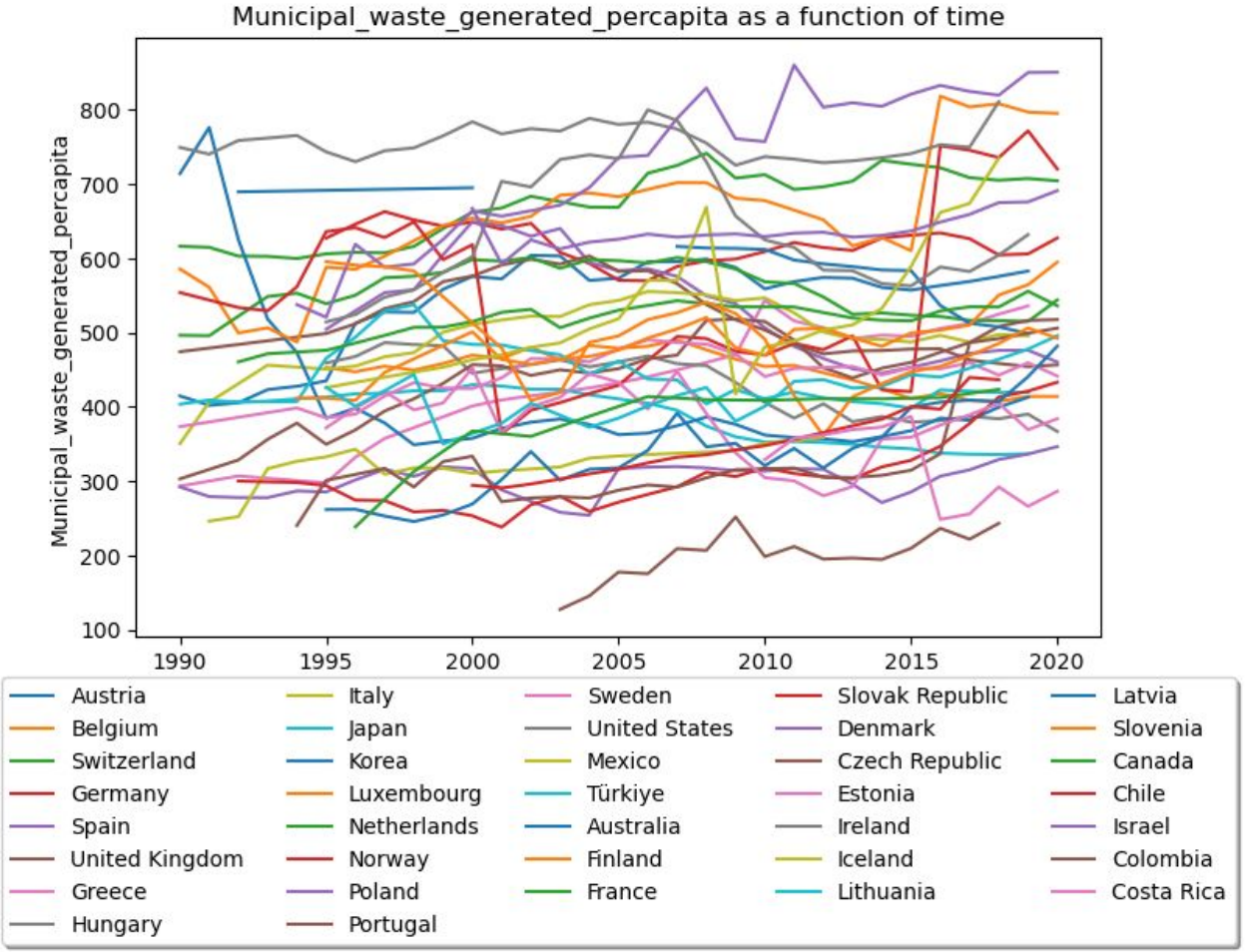
Hypothesis 3

Observations 1

1. The above plot shows the trend of forest area over period of time for different countries.
2. It can be observed that for countries like Australia, Spain, Switzerland, Germany the forest cover increases over time.
3. The forest cover decreases over time for Colombia, Canada, Mexico, Korea and other similar countries.



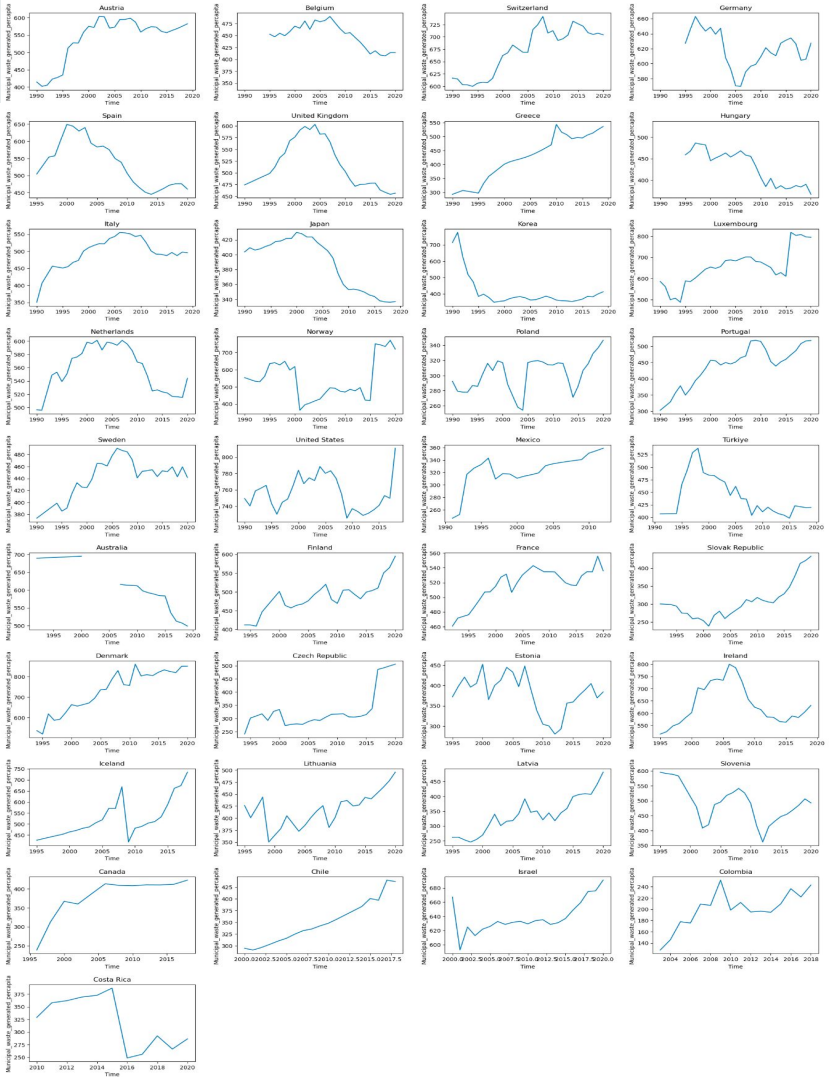
Hypothesis 3



Hypothesis 3

Observations 2

1. Countries show varied trend of Municipal waste generated. While some increase overall, the others show a decreasing trend of generation of Municipal waste.
2. Austria, Switzerland, Greece, Poland, Chile, Israel and others show an increasing overall trend for municipal waste generated per capita.
3. Spain, Hungary, Korea, Japan, Mexico and other similar countries show a decreasing overall trend.

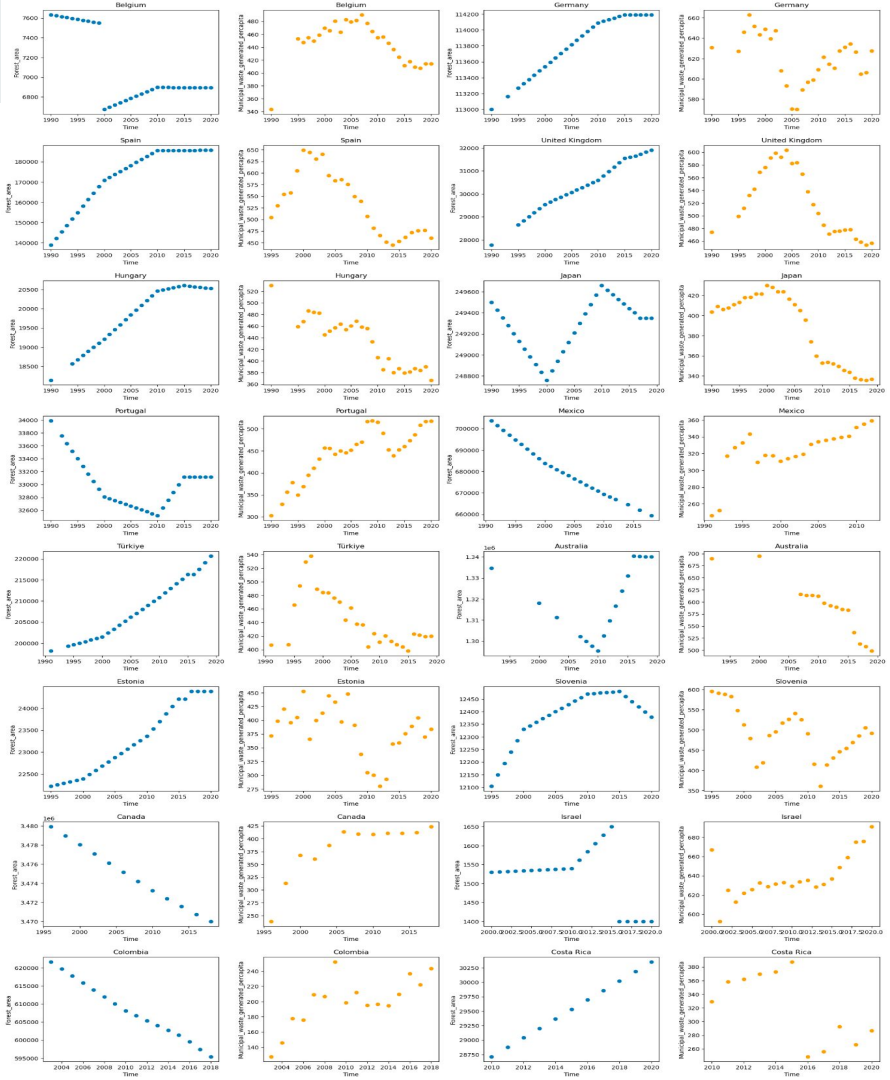


Hypothesis 3

Analysing different country groups based on spearman correlation coefficient

Group 1 corr<0.-25

1. Portugal, Mexico, Canada, Colombia and other similar countries show a decrease in forest area while an increase in the municipal waste generate per capita is observed for these countries.
2. Germany, Spain, United Kingdom, Hungary and other similar countries show an increase in forest area while there is a decrease in municipal waste generated per capita.

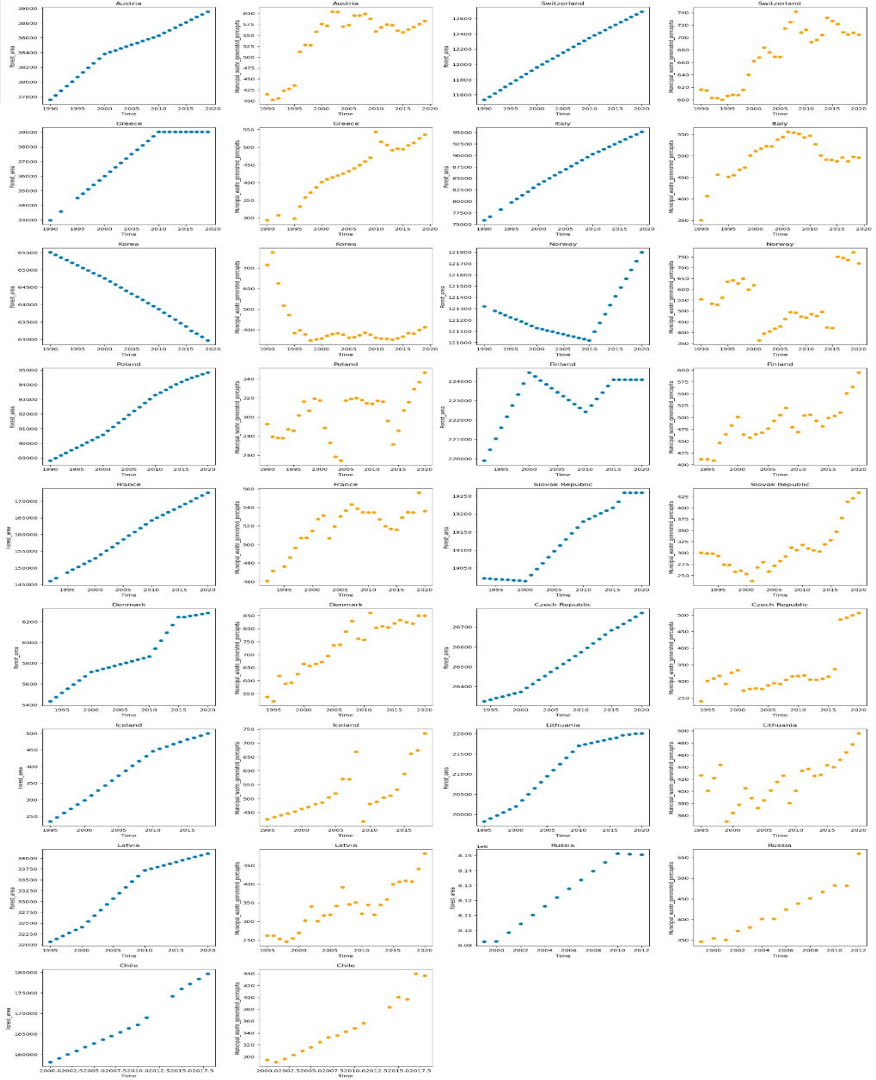


Hypothesis 3

Analysing different country groups based on spearman correlation coefficient

Group 2 corr>0.25

1. Australia, Switzerland, Greece, Italy and other similar countries show an increase in both forest area and municipal waste generated.
2. Korea shows an overall decrease in both forest area and municipal waste generated.

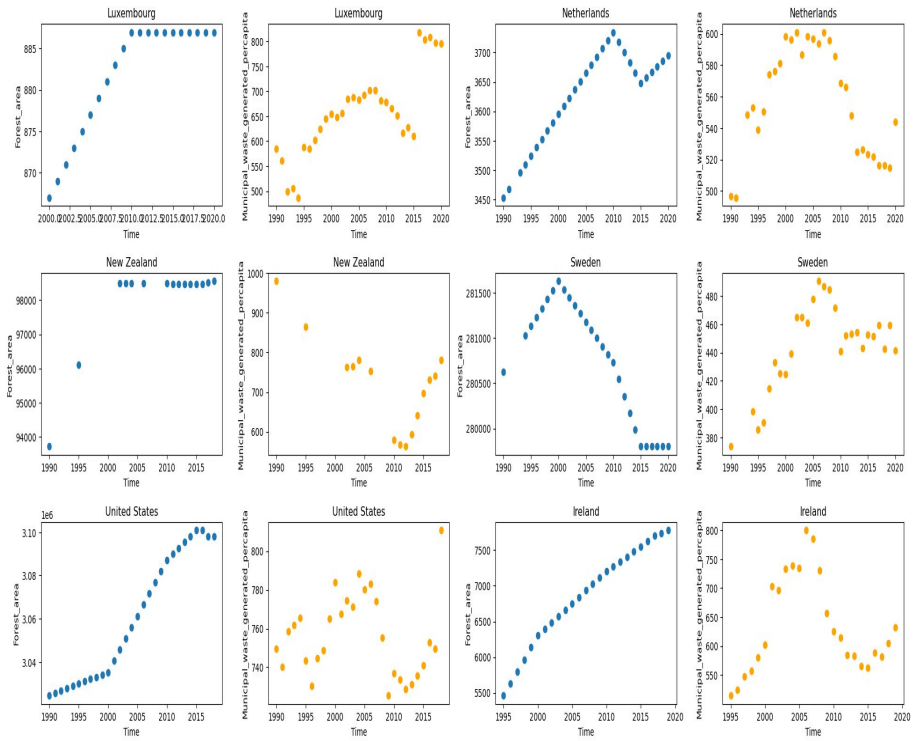


Hypothesis 3

Analysing different country groups based on spearman correlation coefficient

Group 3 -0.25<corr<0.25

1. The countries shown in the above group show least correlation between forest area and Municipal waste generated per capita.
2. For Sweden and Ireland the municipal waste generated per capita initially increases and then decreases while the forest area is monotonically decreasing or increasing.



Next Steps and Limitations

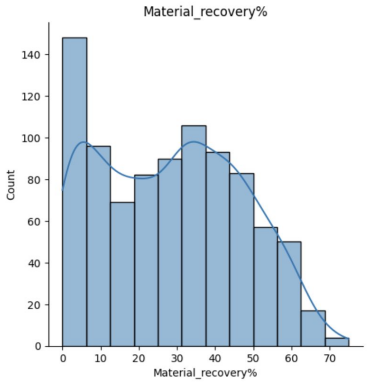
- Correlation does not prove causation. Spurious correlations can exist.
- Panel data regression or ML models were beyond the scope of this project.
- We intend to draw some insights to aid future studies through our analysis.

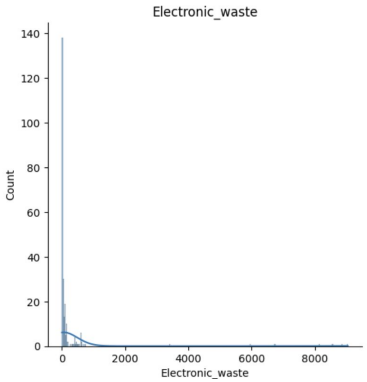
- **In progress**: Doctests, refining the code, and inculcating feedback.

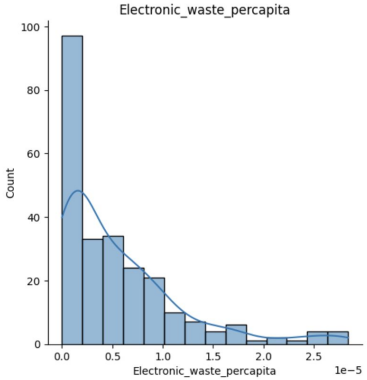
Appendix

Hypothesis 1: Density Plots

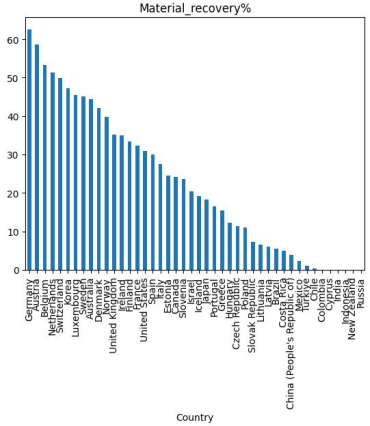
Density plots

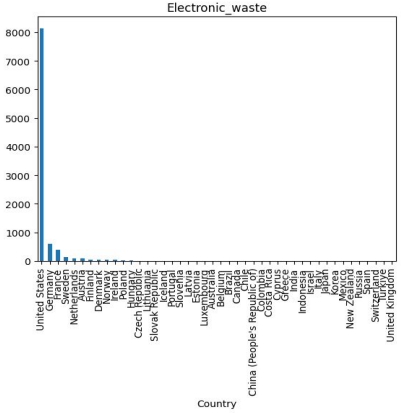


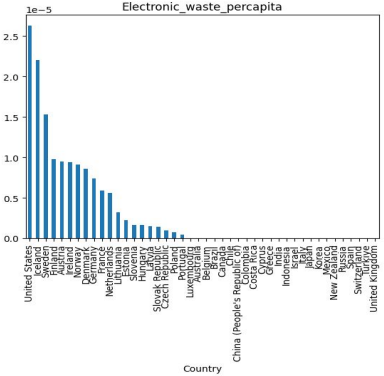




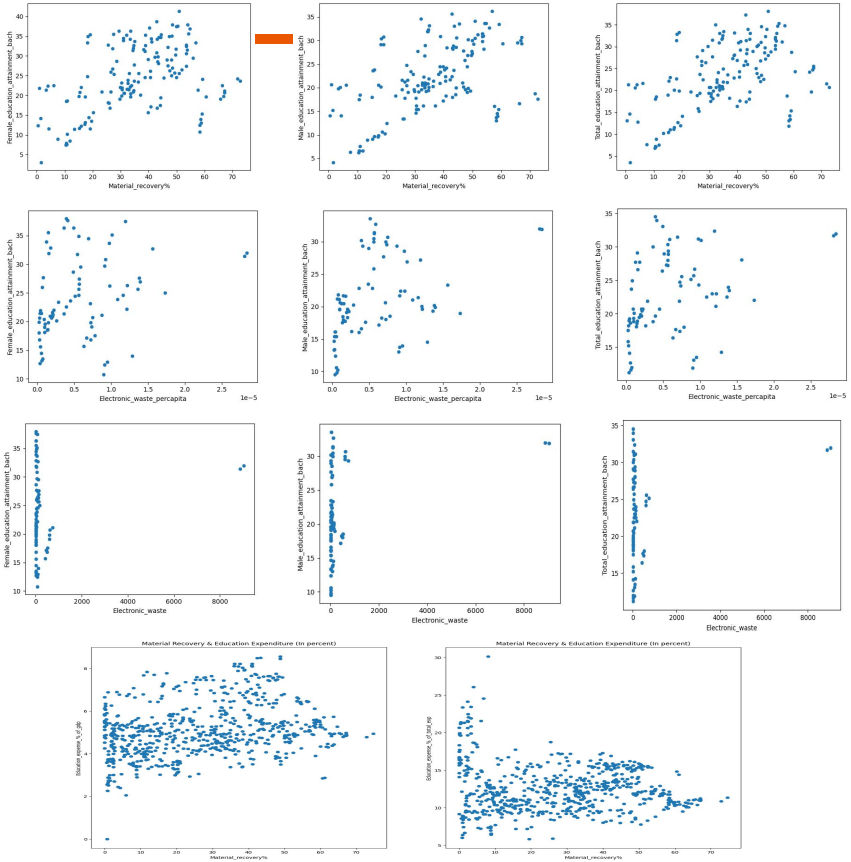
Hypothesis 1: Median share per country







Hypothesis 1: Relationships



- More material recovery % seems to be correlated with higher education attainment.
- There does not seem to be an obvious relationship between education attainment and electronic waste generated per capita.
- There does not seem to be an obvious relationship between education attainment and electronic waste generated overall.
- At higher levels (4-7%) of education expense as % of GDP, there is a linear relationship with material recovery. For education expense as % of total government expense has a linear relationship with material recovery at its lower levels (5-15%).